Variable Frequency FFAGs

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Advanced Accelerator Group Meeting

2 June 2005

Introduction

- Time of flight in FFAGs depends on energy
- If RF frequency doesn't change, this will cause you to get off the RF crest if you accelerate too slowly
- However, if the RF frequency is variable, you can stay on-crest, using as little voltage as you want
- With muons, we have decays: want a high average gradient
- Find cost-minimum lattices with decays where no attempt is made at controlling time of flight
- Compare to cost-minimum lattices with control on time of flight

The Big Table

Minimum total energy (GeV)	2.5	5	10	2.5	5	10
Maximum total energy (GeV)	5	10	20	5	10	20
$V/(\omega\Delta T\Delta E)$	1/6	1/8	1/12	—	—	—
No. of cells	50	65	82	38	47	65
D length (cm)	63	77	97	84	102	119
D radius (cm)	13.4	10.0	7.4	13.3	10.1	7.6
D pole tip field (T)	4.5	5.7	7.1	5.1	6.5	7.9
F length (cm)	96	113	141	113	143	171
F radius (cm)	21.2	16.3	13.1	23.4	19.7	15.2
F pole tip field (T)	2.7	3.5	4.3	3.2	3.8	4.6
No. of cavities	58	49	56	30	36	45
RF voltage (MV)	534	620	704	380	464	566
Turns	4.7	8.2	15.0	6.6	10.8	17.7
Circumference (m)	204	286	400	169	232	350
Decay (%)	4.2	5.1	6.5	4.8	5.4	6.6
Magnet cost (PB)	39.4	37.2	39.1	40.0	40.6	42.7
RF cost (PB)	30.3	35.2	39.9	21.5	26.3	32.1
Linear cost (PB)	5.1	7.2	10.0	4.2	5.8	8.8
Machine cost (PB)	74.8	79.5	88.9	65.7	72.8	83.6
Extra decay cost (PB)	—	—	—	3.1	1.5	1.0
Cost reduction (%)	—	—	—	8.0	6.6	4.9

Analysis

- The cost reductions are relatively modest
  - Cell lengths go up, so RF efficiency goes down: more decays
  - Machine gets shorter, magnet costs go up (aperture increase)
  - Less RF required, this plus linear cost gives reduction
- For all three stages, cost increase is 20% of final RF cost
  - Making the RF frequency variable will cost something!
  - RF cost includes cavity itself plus power, cryostat, etc.
  - Thus, may be larger percentage of cavity cost.
  - Power, cryo costs may also increase!
- Probably not worth the trouble to make RF variable
  - Cost reduction is relatively modest
  - High technical risk
- Maybe only do it for low energy